TEMPORARY NON-VEGETATIVE SOIL STABILIZATION EVALUATION STUDY FOR 2000 - 2001 SEASON

Orange County, California

CTSW-RT-01-066

California Department of Transportation

Environmental Program
1120 N Street, MS-27
Sacramento, California 95814

October 25, 2001

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

Page

TABLES

FIGURES

TABLE OF CONTENTS
(continued)

FIGURES (cont.)

TABLE OF CONTENTS
(continued)

APPENDIXES

TEMPORARY NON-VEGETATIVE
SOIL STABILIZATION EVALUATION STUDY

1.0 INTRODUCTION

This report presents the results of a field study designed to evaluate the performance of several temporary non-vegetative erosion control products at two selected field sites in Orange County California. The procedures used to select the sites and erosion control products, implement field testing of erosion control products, and monitor their performance were conducted in general accordance with the Detailed Study Plan and Experimental Design (the Study Plan [CTSW-RT-01-014]), Sampling and Analysis Plan (SAP [CTSW-RT-01-001]) for the Caltrans Temporary/Permanent, Soil Stabilization Evaluation Study dated March 2001, and the Caltrans Guidance Manual: Storm Water Monitoring Protocols 2nd Edition (Revised July 2000).

1.1 PURPOSE

California Department of Transportation (Caltrans) historically has employed many soil stabilization measures along California roadways. Caltrans has performed studies to evaluate the effectiveness of these measures to control erosion on cut and fill slopes; however, limited information exists on the effect of these measures on storm water quality.

The purposes of this study are to evaluate (1) the potential impact of these products on storm water quality, and (2) the performance of currently used and new temporary non-vegetative soil stabilizers for controlling soil erosion. A goal of Caltrans for this and similar studies is to develop and implement Best Management Practices (BMPs) that meet the Maximum Extent Practical (MEP) standard requirement of the Caltrans' storm water permit.

1.2 SCOPE OF WORK

The key work activities conducted during this study were:

- Review previous erosion control studies completed by Caltrans.
- Evaluate and select sites for field-testing.
- Evaluate and select erosion control products to apply to selected sites.
- Design and construct test plots at each field site and apply the selected erosion control products according to manufacturer's specifications.

- Install storm water monitoring equipment at each site.

- Evaluate the effects the products may have on water quality and monitor the performance of the products for controlling erosion.

- Prepare this report.

2.0 PROJECT OVERVIEW

The following subsections provide a summary of the previous erosion control studies completed by Caltrans and an overview of key elements of the current study, including the site selection process, erosion control product evaluation and selection, and the design and construction of test plots.

2.1 PREVIOUS EROSION CONTROL STUDIES

Previous erosion control studies performed by Caltrans were reviewed as part of the planning and project design process for the temporary non-vegetative soil stabilization measures study. In general, these reports summarize the results of various erosion control products that were applied with the objective of reducing sedimentation and enhancing establishment of vegetation. The reports also include descriptions of the methodologies that were developed for establishing field and laboratory tests and design of small-scale soil erosion study plots. These studies are summarized below:

District 7 Erosion Control Pilot Study, Detailed Study Plan and Experimental Design, Woodward Clyde, May 15, 1998. The objective of this study was to evaluate alternative soil stabilization methods designed to minimize the transport of sediment from cut and fill slopes within Caltrans District 7 right-of-ways. The report summarizes the initial steps of an erosion control study focusing on reducing the quantity of sediment discharged to storm water drainage systems. The report describes erosion control problems within Caltrans District 7 and includes a review of previous erosion related studies and field observation of District 7 sites with erosion problems. The results of the review indicated that although a wide variety of erosion control materials were in use, evaluation of the effectiveness of these measures was not being adequately addressed. The current erosion control practices of Caltrans and other state and federal agencies were also evaluated. These practices include the use of various types of natural fibers and mulches, with the major emphasis on vegetative solutions for erosion control. Field and laboratory studies performed by entities other than Caltrans were also reviewed. This review indicated that much of the available data was not directly relevant because vegetation types or site parameters in the studied sites were not typical for District 7 sites. Areas where there was insufficient data available for erosion control decision making were identified. These included the long-term effectiveness of control measures, native plant establishment techniques, and measurement of erosion rates. Vegetative erosion control candidates were selected for testing and an experimental design and monitoring methodology was established.

Caltrans Roadside Erosion Control Effectiveness Stormwater Monitoring Study, 1997-2000 Summary Report, Districts 7 and 11, August 2000. The purpose of this study was to evaluate the effectiveness of erosion control measures at three sites, two in District 7 and one in District 11, that implemented Caltrans erosion control BMPs. Storm water quality monitoring of inorganic constituents was performed before and after the erosion control measures were implemented. Storm water samples were collected at the sites during a baseline period (1997-1998) prior to the installation of erosion control BMPs and also following implementation of erosion control BMPs (1998-2000). Rainfall for the various monitoring events was also measured. The analytical results of storm water monitoring prior to and following implementation of BMPs were statistically analyzed and compared. Test results indicated limited success at reducing inorganic constituents in runoff from the sites. The study concluded that BMP performance was likely influenced by site-specific installation and maintenance procedures.

Soil Stabilization for Temporary Slopes, URS Greiner Woodward Clyde, November 30, 1999. This document was prepared as a field guide for Caltrans personnel to assist with selecting erosion control products for ongoing construction activities and for final stabilization of disturbed areas. The guide is based on information developed as part of the District 7 Erosion Control Pilot Study (see below). The document includes tabulated data comparing various stabilization products and criteria for product selection. These tables include a qualitative indication of potential impacts to runoff water quality for the various products. The results of this study were used as a screening tool during the product selection phase for this study.

District 7 Erosion Control Pilot Study, June 30, 2000. This report summarizes the results of a study of soil stabilization methods designed to minimize the transport of sediment from cut and fill slopes within Caltrans District 7 right-of-ways. This study follows the pilot study design described above in URS Woodward Clyde, 1998. An evaluation of five surface roughening techniques was performed. The report concluded that several roughening techniques were effective at reducing erosion. The study also evaluated the effects of temporary irrigation on plant density and coverage. A positive short-term effect on seed germination was noted.

Fifteen soil stabilization measures were tested and ranked according to erosion rate and total coverage after two years. These rankings along with cost data were tabulated. The study concluded that many of the stabilization measures were effective at significantly reducing sediment in runoff. Water quality data from storm water runoff at the sites was statistically analyzed and evaluated. Certain wood or fiber based stabilization products were found to increase total organic carbon, biological oxygen demand (BOD), and chemical oxygen demand (COD) in runoff. No specific ranking system for water quality effects was established.

2.2 MONITORING SITE SELECTION

This section describes the criteria used to evaluate candidate sites for testing, the methods used to identify candidate sites, and the two sites selected and constructed for the temporary non-vegetative soil stabilization evaluation study.

2.2.1 Criteria For Evaluating Candidate Sites

General criteria were developed to evaluate candidate sites. The eight criteria listed below are considered relevant for selecting sites for testing of temporary and permanent erosion control products.

1. Personal Safety

Safety at field sites during construction, monitoring, and sampling is a mandatory priority. As such, selected sites needed to adhere to all Caltrans safety requirements (e.g., distance from roadway). Other safety mandates adopted for this study included lane closures only during construction and no redirection of traffic flow during monitoring or sampling. Sampling equipment and work areas needed to be readily accessible to personnel without safety concerns.

2. Site Monitoring and Sampling Logistics

Sites must allow storm water runoff from test plots to be conveyed into existing drainage systems with only relatively minor modifications. Existing drainage systems also needed to accommodate storm water monitoring using automated monitoring equipment. Furthermore, selected sites must allow independent collection and sampling of runoff from individual test plots (i.e., not allow run-on from non-test areas).

3. Site Accessibility

Selected sites needed to be readily accessible to Project Team offices on a 24 hours a day, 7 days a week basis. This facilitated site inspections, monitoring, and sample collection and reduced travel times, costs, and sampling logistics. Potential sites in Districts 6 and 12 were evaluated because of their proximity to Project Team offices in Orange County and Fresno, California.

4. Site Conditions and Constraints

When possible, the study targeted sites recently constructed or regraded, or sites where vegetative erosion control measures had not been adequately established. Also, the Project Team targeted sites that have relatively uniform conditions within a given site, such as soil type and slope inclination and height. Constraints such as sensitive animal habitats, aesthetic issues, and other site-specific issues identified by Caltrans were key considerations.

5. Site Area

Individual test plots needed to be large enough to provide sufficient runoff quantity to measure runoff flow and collect storm water samples with automated samplers. The minimum flow rate accurately measured for this study was approximately 0.006 cubic feet per second, which was accomplished using a flow sensor in a 6-inch Palmer-Bowles flume. The minimum plot size to fulfill this requirement is approximately 0.1 acre (calculated using the Rational Method).

Sites were considered if they accommodated at least three adjacent test plots of similar size to be constructed. This allowed two or more products and an untreated bare soil plot (referred to herein as a control plot) to be tested concurrently. Testing more than one product at a single site helped to reduce variations inherent between sites, such as sunlight exposure, rain intensity, soil conditions, and others.

6. Equipment Security

When possible, sites were preferred that restricted or limited public access for security of equipment and safety.

7. Non-interference with Caltrans Activities

Sites were selected where testing of erosion control products would not interfere with current or anticipated future Caltrans construction projects or other activities.

8. Power and Cellular Phone Access (Preferred)

Access to power and cellular phone coverage at a candidate site was preferable, but not mandatory.

2.2.2 Methods to Identify Candidate Sites

Using the section criteria above, the Project Team identified potential sites in Districts 6 and 12. Districts 7 and 11 were also contacted regarding this study, but no candidate sites were evaluated in these districts during the 2000-2001 study season.

In District 12, the Project Team performed a reconnaissance along Routes 73, 241, and 261 to identify potential sites. Several sites along these routes were observed, photographed, and evaluated, including a site identified by District 12 at the Route 73/55 interchange. Aerial photographs, topographic maps, and/or as-built plans were also obtained from District 12, when available, to aid in identifying sites.

Two candidate sites in District 12 were selected for approval by District 12 and Caltrans Headquarters. District 12 and Caltrans Headquarters subsequently approved the two sites for testing. These sites are described in the following section.

2.2.3 Description of Selected Test Sites

The two test sites approved by Caltrans for testing are adjacent to Route 73 in District 12. The sites will be referred to hereafter as the 55S and 73S sites. The general location of the sites are shown on Figures 1 and 2, respectively. A description of each site is provided below.

<u>55S Site</u>

The 55S site was the first site constructed for this study and is located at the Route 73/55 interchange in Costa Mesa, California. It is the site selected by District 12 and is an interior fill slope of the exit ramp loop connecting Route 73N with Route 55S. The fill slope has an average inclination of approximately 2:1 (horizontal:vertical) and varies between approximately 20 and 30 feet in height.

The site has an existing rock trench along the toe of the slope, which conveys runoff from the slope to an inlet near the trench’s northern end. During testing of storm events, runoff was discharged to this drainage system after it flowed through the conveyance system constructed for this study (see Section 3.0).

<u>73S Site</u>

The 73S site was the second site constructed for this study and is located along Route 73S between approximately Highway Station Numbers 968 to 974. The site is a south-facing fill slope with an average inclination of approximately 2:1 and has an existing unpaved road and concrete v-ditch at about mid-slope. The existing v-ditch collects runoff from the upper half of the slope and conveys it to a descending concrete v-ditch near the southern end of the test site. The descending v-ditch transports the runoff down to the toe of the slope. During testing of storm events, runoff was discharged to this drainage system after it flowed through the conveyance system constructed for this study (see Section 3.0).

Plots were constructed over the upper half of the fill slope, just above the existing v-ditch and unpaved road. Height of the slope within the plots ranged from approximately 40 to 60 feet.

2.3 EVALUATION AND SELECTION OF PRODUCTS

The Study Plan provided a summary of non-vegetative erosion control products potentially suitable for inclusion in the temporary non-vegetative soil stabilization measures study. A description of criteria used to select the products is described below.

2.3.1 Selection Criteria

Product selection was based on the following:

1. **Impact on Storm Water Quality**
   Erosion control products that may have the potential to adversely impact storm water quality (based on previous Caltrans studies and product types) were selected for testing.

2. **Effectiveness of Erosion Control**
   Products that are potentially effective in controlling soil erosion when used according to the manufacturer's recommendations were selected for testing based on manufacturer claims and previous studies of similar products.

3. **Installation Costs**
   The cost to install products identified for possible inclusion in this study ranged from approximately $450 to $65,000 per acre; however, temporary soil stabilization products selected for testing in this study ranged from about $450 to $1,100 per acre. The lower range of costs reflects temporary and cost effective short term solutions for slope stabilization projects.

4. **Ease of Application and Cleanup**

The products selected for potential use during this study are relatively easy to install and cleanup of installation equipment is generally accomplished by rinsing/washing spray equipment with water.

5. Availability
The products are readily available for delivery to a site. Lead time generally ranges from several days to approximately two weeks.

6. Currently Used by Caltrans
Products that are currently used or are anticipated to be used by Caltrans were selected.

7. Use as Non-Vegetative Measure
Products that can be used as a non-vegetative erosion control measure by Caltrans were selected.

2.3.2 Selected Products

Based on evaluation of available temporary soil stabilization products and general conformance with the selection criteria noted above, a total of seven products were recommended to Caltrans for evaluation in this study. Caltrans approved these products for testing in this study. Two products were selected for the 55S site: EarthGuard™ and Soil Sement. Five products were selected for the 73S site: Airtrol, Tacking Agent III™, Top Coat, Chemco 9107GD (a polyacrylamide referred to hereafter as PAM), and UltraTack. Material Safety Data Sheets for the selected products are provided in Appendix A.

Specific information regarding the manufacturer information and application for each product is summarized in Table 1. A brief description and general use of each product as a soil stabilizer is presented below.

2.3.2.1 EarthGuard™

Primary constituents in EarthGuard™ include polyacrylamide, ammonium polyacrylate, a water-in-oil emulsion, and mulch. EarthGuard™ has a high molecular weight and specific charge density, which enhances soil particle aggregation. According to the manufacturer, the product is appropriate for temporary erosion control lasting up to one season. The actual length of the product effectiveness is dependent upon a number of factors including climate, slope inclination, and soil/geologic conditions.

According to the manufacturer, EarthGuard™ is effective for erosion control, slope stabilization, dust abatement, storm water runoff and silt control, and water quality control. Additionally, it can be effective for dust suppression along roadways, but is not intended for vehicular traffic.

2.3.2.2 Soil Sement

Primary constituents in Soil Sement™ include an acrylate/vinyl acetate polymer and emulsifying agents. Soil Sement is used primarily for soil stabilization and as a dust control agent. This product is not generally used to support vehicular traffic.

2.3.2.3 Airtrol

Primary constituents in AIRTROL™ include Plaster-of-Paris, gelatin, and cellulose fiber mulch. AIRTROL™ is cementious plaster binder produced from high-purity gypsum and applied in conjunction with a mulch through a hydraulic process. The product forms a uniform protective crust-like barrier that reduces water and wind induced erosion.

AIRTROL™ is typically used for erosion control and as a cover for establishing vegetation on disturbed slope areas. The product is intended to be used during the initial establishment of vegetation.

2.3.2.4 Tacking Agent III™

Primary constituents in Tacking Agent III™ include polyacrylamide and other acrylamide polymers. Tacking Agent III™ is used as tackifier for binding mulch and seed in hydroseeding operations and can be used without mulch as a temporary soil erosion control measure.

2.3.2.5 Top Coat™

Primary constituents in TOPCOAT™ include guar gum, cellulose fiber and unspecified proprietary fillers. TOPCOAT™ is designed to be used as a daily cover material for landfills. The manufacturer indicated that the product has also been used as an effective erosion control measure. The manufacture reports that a single application of TOPCOAT™ near Phoenix, Arizona has been effectively controlling erosion for two seasons. Because it is a paper product, vehicular traffic should be avoided.

2.3.2.6 PAM

The primary constituent in PAM (Polyacrylamide; Chemco 9107GD) is polyacrylamide. PAM is a long-chain organic polymer developed to clarify drinking water. PAM has also been used for erosion control, enhanced infiltration and nutrient removal. If the treated area is disturbed by foot and/or vehicle traffic the product will not be effective and will need to be reapplied.

2.3.2.7 Ultra Tack™

Primary constituents in Ultra Tack™ include polyacrylamide and mulch. Ultra Tack™ is an anionic polyacrylamide that is typically used as a tackifier and binding agent. The product is typically mixed with a mulch and a hydroseed mixture and sprayed on the ground surface.

2.4 TEST PLOT DESIGN

Test plots were designed with the intent of measuring flow, and collecting and sampling storm water runoff from distinct and separate test plot drainage areas. Key components of the design were: 1) isolating plots so that runoff from each plot could be collected independently without influence from surrounding non-test areas; 2) calculating, using the Rational Method, a minimum plot size that provides an adequate quantity of runoff for typical storms in Orange County; and 3) designing an effective collection and measuring system for runoff from each plot. Each of these is discussed below.

2.4.1 Plot Borders

To monitor plots independently, bordering was installed around the limits of each plot. Considering the size of the plots (0.1 to 0.2 acre), slope gradients, and other site and study constraints, it was necessary to select a material that was inert and could be readily installed. Plastic paneling used for root control was selected that fulfilled the study requirements. The panels were approximately 18 inches high, interlocking, and relatively watertight at joints. They were buried mid-height in the soil as a protective barrier around the plots. In order to eliminate potential overspray of products into adjacent plots during application and mixing of runoff between plots during storm events, a gap of typically about 10 feet wide was used between borders of adjacent plots. Straw mats were placed on the bare soil in the gaps between plots for erosion control. Because of site constraints, a gap does not exist between the control plot and a test plot at the 55S site.

2.4.2 Plot Size

Plots needed to provide sufficient runoff from typical southern California storm events to allow flow measurements and sample collection using automated runoff monitoring equipment. According to the manufacturers of the equipment, flow rates of about 0.006 cubic feet per second (cfs) and higher can be accurately measured using the monitoring equipment selected for this study. Rainfall/runoff analyses were performed to estimate the minimum plot size needed to provide this flow rate during several storms in a typical year. These analyses are described below.

Historical rainfall intensity-duration-frequency (IDF) data were collected from the Orange County Hydrology Manual. The IDF data were not usable in their published form because the most frequent event listed is the 2-year storm, which has a probability of occurrence of only 50% during any year. However, sufficient data were available to calculate rainfall intensity for more frequent events and it was estimated that the 1.01-year (99% exceedance probability or 2.33 standard deviations below the mean) storm had an intensity of about 0.29 in/hr. This storm event was used in the analyses because of the probability that it would be met or exceeded several times in a year with average rainfall.

Runoff coefficients were estimated using the methodology described in Figure 819.2 (Runoff Coefficients for Undeveloped Areas) in Chapter 810 of the Caltrans Highway Design Manual, which accounts for slope, soil type, cover, and surface storage. Calculated runoff coefficients were reduced by about 20% because the data in Figure 819.2 are for the 5-year to 10-year storm. The runoff coefficient of each test plot after product application was assumed to be 0.2 in the analyses.

Results of the analyses indicate that a 1.01-year (99% exceedance probability) storm of 30 minutes duration will produce an average runoff flow rate of about 0.006 cfs from a 0.1 acre plot with a runoff coefficient of 0.2. This flow rate is sufficient for flow measurement using the automated monitoring equipment. These results suggest that in an average year there should be several storms that produce measurable runoff from a 0.1-acre test plot.

The limited area of the 55S site could accommodate only three 0.1-acre plots or two 0.15-acre plots. To allow at least two products to be tested at the 55S site, 0.1-acre plots were selected (two test plots and one control plot). Conversely, the 73S site did not have such area constraints. To account for uncertainties in runoff coefficients, weather, and other factors, the plots at the 73S site were increased to approximately 0.2 acre.

2.4.3 Runoff Collection and Sampling

As previously discussed, a requirement of this study was that runoff from each plot had to be collected, measured, and sampled independently from other plots. To this end, collection and monitoring facilities were designed for each plot that consisted of a concrete v-ditch, level concrete pad, 6-inch Palmer-Bowles flume, Sigma 900 Max automatic sampler, and a Sigma 950 flow meter. The concrete v-ditches were constructed along the entire length of the bottom of each plot to collect storm water runoff. They were gently sloped to drain to one corner of the plots and housed the flume at their downstream end. Intake ports for the automatic samplers were installed in the bottom of the v-ditches upstream of the flume. The flume acts as a restriction in the v-ditch to produce a high velocity critical flow and a change in the level of the liquid flowing through the flume. The flow rate is determined by measuring the head on the flume at a single point using a bubbler sensor (bubbler). The flume type and dimensions were programmed into the flow meter to obtain the proper head-flow rate relationship for each of the monitoring installations.

3.0 FIELD TEST IMPLEMENTATION

This section describes the methods used to construct and monitor the plots at the 55S and 73S sites.

3.1 SITE CONSTRUCTION

Test areas were divided into two type plots, control and test. Control plots were untreated bare soil slopes that did not contain a soil stabilizers and were monitored as a control. Test plots had a soil stabilizer applied to the slope.

Construction of the 55S site began on January 18, 2001 and was completed (without product applications) on January 28, 2001. The site configuration allowed three plots to be constructed. The three plots (12-201 through 12-203) are approximately 0.1 acre each, have similar dimensions, and encompass nearly the entire fill slope at the site. The plan view layout of plots at the 55S site are shown on Figure 3.

Construction of the 73S site began on February 5, 2001 and was completed (without product applications) on February 20, 2001. The five test plots (12-205 through 12-209) are approximately 0.2 acre each, have similar dimensions, and extend from the pre-existing unpaved road to the top of the slope. Control plot 12-204 was initially approximately 0.1 acre for the first two storm events (storm events February 25-26, 2001 and March 6, 2001) and extended upslope from the pre-existing road to approximately midway between the road and top of the slope. After the March 6, 2001 storm event, the size of control plot 12-204 was increased to 0.2 acre by extending the panel bordering to the top of the slope. At 0.2 acre, control plot 12-204 is longer and shorter than the five test plots at the 73S site. The plan view layout of the plots at the 73S site is shown on Figure 4.

Construction procedures for the plots at the 73S and 55S sites were similar and are discussed below. Photographs showing aspects of plot construction are shown on Figures 5 and 6 for the 55S and 73S sites, respectively.

Control plots and test plots were initially prepared by clearing and grubbing, grading, and roughening the slope by track walking. After track walking, the limits of the plots, v-ditches, and pads were laid out and staked. A backhoe excavated the trenches for the v-ditches and the level pads for the automatic samplers. Wood forms were installed in pad areas and along the trenches (where needed). Flumes were installed at the downstream end of the trenches. Concrete was then poured to create the equipment pads and v-ditches. Low retaining walls consisting of cinder block were constructed on the upslope side of the concrete pads. A buried sedimentation basin (approximately 4 feet by 4 feet by 4 feet deep) was also constructed of cinder block immediately downstream of the flume at control plot 12-204 (73S site).

Shallow trenches for the plastic panel bordering were hand excavated along the edges of the plots. The panels were installed in the shallow trenches and then the trenches were backfilled with excavated spoils and tamp compacted. Panels were typically buried approximately 9 inches below ground surface.

3.2 PRODUCT APPLICATION

The soil stabilization products were applied by the manufacturer or by a hydroseeding company selected by the manufacturer. An exception to this is the PAM product. The product supplier of the PAM (Chemco) did not select an applicator for their product. Consequently, the Project Team selected a hydroseeding company to apply the PAM product. Application of the products is described in detail below.

3.2.1 55S Site

EarthGuard™ and Soil Sement were applied to test plots 12-202 and 12-203, respectively, at the 55S site. Photographs showing the product application process are present on Figures 7 and 8. Both products were applied on January 29, 2001 under damp climatic conditions.

Precipitation occurred the night of January 28, 2001. The slopes were, however, relatively dry during application because they had been covered with plastic sheeting on January 28, 2001 before precipitation had occurred.

Terra Novo supplied the EarthGuard™ product and selected Sanders Hydroseeding to apply EarthGuard™ to the slope. It was applied as a slurry mixture under pressure at a rate that ranged between about 6 to 7 gallons per acre of land. Sanders Hydroseeding mixed the product on site with a 1,500-gallon hydromulch machine equipped with continuous mechanical agitators to create a relatively homogenous slurry during application. The slurry mix ratio consisted of one gallon of EarthGuard™ product, approximately 227.5 pounds of mulch, and 300 gallons of water. The product was sprayed over the entire slope with a standard 2-inch fire hose from the slope crest down to the toe.

Midwest Industrial Supply, Inc supplied the Soil Sement product. The manufacturer mixed the product at their facility at a four-to-one water to product ratio, and transported the emulsion to the site in a 1,500-gallon hydromulch transport truck. The emulsion was applied by the manufacturer by spraying onto the slope under pressure at a rate of 670 gallons per acre (1 gallon per 65 square-feet) from the slope crest to the slope toe.

3.2.2 73S Site

Tacking Agent III™, Aitrol, UltraTack, PAM, and Top Coat were applied to test plots 12-205 through 12-209, respectively, at the 73S site. Photographs showing the product application process are shown on Figures 9 through 13. Hydroplant applied Tacking Agent III™. Sanders Hydroseeding applied Airtrol, Ultra Tack, PAM, and Top Coat.

UltraTack supplied by Terra Novo, and PAM supplied by Chemco were the first two products applied at the 73S site. Both products were applied on February 21, 2001 under dry, cloudless and warm conditions. Airtrol is manufactured by U.S. Gypsum and was applied on February 22, 2001. Top Coat is manufactured by Central Fiber Corp. and was applied on February 21 and 22, 2001 under similar dry and warm climatic conditions. Tacking Agent III™ is manufactured by Profile Products, Inc. and was initially applied on February 24, 2001 under wet conditions. It was reapplied to the slope on March 16, 2001.

Ultra Tack was mixed into a slurry on site using a 1,500-gallon hydromulch machine equipped with mechanical agitators, at a ratio of 5 pounds of product to 325 pounds of mulch and 600 gallons of water. The slurry was continuously agitated to maintain a relatively homogenous mixture during the application process. The slurry was sprayed over the slope surface with a 2-inch diameter fire hose at an application rate of 25 pounds of product per acre of land. The product was applied from the slope toe up to the crest. Climatic conditions were warm and dry after application, enabling the product mixture to thoroughly dry and set.

The PAM soil stabilizer was mixed on site inside a 500-gallon polymer tank. Five ounces of the product and 400 gallons of water were thoroughly mixed by jet agitation (re-circulated through a pump and the tank until thoroughly mixed). Continuous agitation was not required for the mixture to maintain its homogenous state during application. The mixture was applied from the slope toe to the slope crest.

Airtrol was mixed on site using a 1,500-gallon hydromulch machine equipped with mechanical agitators. The Airtrol mixture contained 1,000 pounds of the gypsum product, 300 pounds of mulch and 600 gallons of water. The slurry was continuously agitated during application to maintain a homogenous state. A 2-inch fire hose was used to pressure-spray the product slurry onto the slope from the slope toe to slope crest, at a rate of 5,000 pounds per acre of land. Dry and warm climatic conditions enabled the product to thoroughly dry and set.

Top Coat was also mixed with a 1,500-gallon hydromulch machine equipped with mechanical agitators. The mix ratio was 700 pounds of product to 1,000 gallons of water. The mixture was continuously agitated during application, and was sprayed onto the slope with a 2-inch fire hose at a rate of 3,500 pounds per acre of land. Because a limited supply of Top Coat product was delivered to the site on February 21, 2001, the hydroseeder applied the mixture over a two-day period. On February 23, 2001 the product was applied to the upper third portion of the slope. The product application for the remainder of the slope was completed the following day. Dry weather allowed the product to set and dry.

Tacking Agent III™ was the last product to be applied at the 73S site. The product was applied to the entire slope on two separate occasions, February 24, 2001 and March 16, 2001. In both applications, the 16 pounds of product was mixed with 500 gallons of water in a hydromulch machine that was equipped with continuous mechanical agitators. The product was applied both times without mulch, which according to the manufacturer, is an acceptable application method. The mixture was sprayed from slope crest to toe at a rate of 80 pounds per acre of land. Precipitation within about two hours after the first application did not allow ample drying time, and prevented the product from completely drying and adhering to the slope. Consequently, Tacking Agent III™ was reapplied on March 16, 2001 under dry climatic conditions, allowing the product to thoroughly dry. However, during both applications, it was observed that a portion of the product did not adhere to the slope and ran off the plot.

3.3 SITE MAINTENANCE

Maintenance activities were conducted at the 55S and 73S sites following construction of the plots and application of the erosion control products. Activities included visual inspection of the plots and collection systems after each storm event, visual inspection of the automatic samplers prior to storm events, and repairs and maintenance of these facilities on an as needed basis. The v-ditches typically required only minor maintenance consisting of removing accumulated sediment and constructing weirs in the v-ditches for the control plots. The weirs were placed in the v-ditches to help control sediment and reduce clogging of the automatic samplers. The sedimentation basin for control plot 12-204 needed to be emptied of sediment and runoff after each storm event. The plots did not require maintenance, except for a shallow soil slump that formed at the northern border of plot 12-202 during a storm event. This required minor repair to the bordering panel and filling the cracks caused by the slope movement. Most of the maintenance involved the automatic samplers and related equipment, which is described in more detail below.

Operation and maintenance of the automated samplers at each site was conducted in accordance with the manufacturer's specifications and Caltrans' most current monitoring guidelines manual. Prior to each storm event, the sampling and flow measurement equipment was inspected in preparation of a pending storm event in accordance with a Pre-Storm Monitoring Equipment Inspection Checklist. The primary maintenance activity related to the automated sampling equipment involved occasional problems with suspended sediment during certain rainfall events, which tended to clog the auto sampler and inhibit water sample collection. During and between storm events, sediment and debris were removed from the bottom and in the general vicinity of v-ditches constructed to convey storm water runoff from the base of the plots. After and between storm events, the rain gauges and sampling equipment were inspected and cleaned to remove sediment and miscellaneous non-study related debris that accumulated during the previous storm. After cleaning, the rain gauges and sampling equipment were calibrated and their batteries were inspected to ready the equipment for the next storm event. In addition, storm information was retrieved from the data loggers on the automated sampling equipment and data loggers were reset for the next sampling event. This information was recorded on a Post-Storm Equipment Checklist.

3.4 EROSION CONTROL MONITORING

Monitoring was performed at each test plot to evaluate the performance of erosion control products with regard to storm water runoff quality and to assess their effectiveness for controlling erosion during storm events. A description of the methods used to collect storm water runoff samples is provided in Section 4.0.

To assess the effectiveness of the products for erosion control, visual monitoring of the test plots was conducted during and after storm water sampling events. Visual evidence of erosion was recorded, such as rills and gullies, raveling, and sediment accumulation in v-ditches. Photographs of the plots were taken after storm events for comparison. Apparent weathering or degradation of the erosion control materials was also noted when observed.

4.0 DATA COLLECTION AND QUALITY ASSURANCE/QUALITY CONTROL

During this study, storm water samples were collected during selected storm events and were analyzed to provide data to assess the quality of storm water runoff from the control and test plots at the 55S and 73S sites. Samples could not be collected from plots where a storm event did not provide a sufficient volume of storm water runoff for analysis. The storm events in which samples were collected for each plot are summarized in Table 2.

The storm water sample preparation and collection procedures were conducted in general accordance with the Study Plan and SAP. A general summary of the general storm water sampling procedures including selection of the storm to be monitored, field measurements, and observations made during each storm monitoring event, and the methods used to collect, preserve, and handle storm water samples is provided in Appendix B.

Quality assurance/quality control procedures were implemented in general accordance with the SAP. A general summary of the laboratory analysis, field and laboratory quality assurance/quality control samples and procedures, data management and validation protocols, and data reporting conducted during this study are summarized in Appendix C.

In addition to storm water runoff samples, soil samples from the control plots and samples of each product applied were collected and submitted for laboratory analysis. In general, the soil and product samples were analyzed for the same metals and other inorganic constituents as the storm water samples. The soil and product data were used to help assess the potential export of dissolved and suspended constituents into storm water runoff from the products and site soils.

5.0 FINDINGS

This section presents the findings of the temporary non-vegetative soil stabilization study for the 2000-2001 storm monitoring season. The following sections present the rainfall data and characteristics for storm events monitored during this study, chemical results for soil samples from the control plots and product applied to the test plots samples, and a summary of specific data collected during each monitoring event including storm water quality runoff data and observations made to the erosion characteristics of each control and test plot.

5.1 STORM EVENT DATA

Precipitation during monitored storm events was characterized by total rainfall, duration of rainfall, and peak and effective average intensities. Peak average intensity (PAI) is defined herein as the maximum average intensity of a peak sub-event during a storm event. More specifically, PAI of a storm is obtained by identifying the peak sub-events of the storm and then calculating an average intensity for these sub-events by dividing the cumulative rainfall during each peak by its duration. The effective average intensity (EAI) of a storm event is calculated as the ratio of the sum of the cumulative rainfall for the sub-events identified and the sum of their duration.

55S Site

From February 12 through April 30, 2001, a total of five storm events meeting Caltrans monitoring criteria (February 12, February 25-26, March 6, April 7, and April 21) occurred at the 55S site. The February 12 and 25-26 storm events produced sufficient runoff to collect storm water samples from all the plots at the 55S site. The March 6 storm event produced sufficient runoff to collect a storm water sample from only one (12-202) of the three plots at the 55S site. The April 7 and April 21 storms did not produce sufficient runoff from the 55S plots to collect samples.

Total rainfall for the five events ranged from 0.16 to 1.41 inches with peak average rainfall intensities ranging from 0.28 to 0.56 inches per hour.

73S Site

Four storm events meeting Caltrans monitoring criteria (February 25-26, March 6, April 7, and April 21) occurred at the 73S study site. The February 25-26 and April 7 storm events produced sufficient runoff to collect storm water samples from all the plots at the 73S site. The March 6 storm event produced sufficient runoff to collect a storm water sample from only one (12-207) of the plots at the 73S site. The April 21 storm produced sufficient runoff to collect samples from all the 73S plots, except plot 12-209.

Total rainfall for the four events ranged from 0.3 to 2.68 inches with peak average rainfall intensities ranging from 0.16 to 1.08 inches per hour.

The largest rain event for both study sites occurred on February 25-26 and the storm with the greatest rainfall intensity occurred on April 21, 2001. Characteristics of the storm events (i.e., PAI and total rain) are shown on Figure 14. Figure 15 shows the correlation between EAI and PAI for the 2000-2001 study storm events.

5.2 SOIL SAMPLING RESULTS

Three soil samples were collected from the bare plots (12-201 and 12-204) and were submitted for laboratory analysis of metals. The soil sample results and calculated average metal concentration data for each site are summarized in Table 3.

5.3 PRODUCT SAMPLING RESULTS

Samples of the product applied to each of the test plots (12-202, 12-203, 12-205, 12-206, 12-207, 12-208, and 12-209) were submitted for laboratory analysis of metals and other inorganic and physical storm water runoff quality parameters. The results of the product analyses are presented in Table 4.

5.4 STORM WATER RUNOFF MONITORING RESULTS

This section presents the findings of field observations made related to erosion of plots and the results of storm water quality runoff samples collected during each monitoring event at the 55S and 73S sites.

5.4.1 55S Site

5.4.1.1 Visual Observations

At the 55S site, the control plot (12-201) provided the baseline for comparing the effectiveness of erosion control measures using EarthGuard™ (12-202) and Soil Sement (12-203) products. The following sections summarize the observations made during the course of storm events between February 10 and April 21, 2001 at this site. The occurrence and approximate percentage cover of vegetation growth on the 55S site plots during 2000-2001 study storm season are summarized in Table 5.

Control Plot (12-201)

Figure 16 shows a time-series progression of control plot (12-201) over the 2000-2001storm monitoring season. As shown on Figure 16, soil erosion was observed at the bare plot with the beginning of the first storm event on February 10, 2001. During this first storm event, rills formed throughout the control slope with the most significant erosion occurring in the northern portion of the plot. The erosion was evidenced by heavy loading of fine and coarser-grained sediment in the v-ditch at the toe of the plot, which required constant removal during intense portions of the storm. The heavy sediment load impeded the accuracy of measurements obtained from the flow monitoring equipment and clogged the intake of the automatic sampler during intense portion of the storm. The second storm on February 25-26 had similar intensity and caused continued heavy erosion of the control plot. Storm events on March 6, April 7, and April 21, 2001 contained considerably less rainfall and produced proportionally less erosion of the control plot.

As shown on Figure 16, sparse vegetation began to occupy the control plot by the March 6, 2001 storm monitoring event. The vegetation density continued to increase over the remaining 2000- 2001 storm monitoring season.

EarthGuard™ (12-202)

Figure 17 shows a time-series progression of the EarthGuard™ test plot over the 2000-2001storm monitoring season. Based on field observations, there was little to no evidence of soil erosion from the EarthGuard™ test plot (12-202) during the five storm events. Minor evidence of foaming was observed in the runoff discharged from the flume during the first storm event.

Following the March 6, 2001 storm event, a shallow slump was observed about two-thirds of the way up the slope near the northern portion of the test plot. The slump appeared to move down slope approximately one to two inches and created surrounding cracks up to two inches in width. Following the March 6, 2001 storm, the cracks were filled with soil and no further movement of the slope was observed during or after the April 7 and April 21, 2001 storm events. Of three test plots at the 55S site, the EarthGuard™ test plot appeared to have the lowest sediment accumulation in the v-ditch and sampling equipment during the storm events.

As shown on Figure 17, sparse vegetation began to occupy the EarthGuard™ plot by the February 25-26, 2001 storm event. The vegetation density continued to increase over the remaining 2000-2001 storm monitoring season.

<u>Soil Sement (12-203)</u>

Figure 18 shows a time-series progression of the Soil Sement test plot. During the storm events, minor soil erosion was observed and removal of sediment from the flume was occasionally required. Sediment loading impeded the accuracy of flow measurements and increased the number of sample aliquots collected during intense portions of the storm events on February 10, February 25-26, and April 7, 2001. Moderate evidence of foaming was observed in the runoff discharged from the flume during the February 10 and February 25-26, 2001 storm events.

Slight rill formation was observed near the northwest and southeast borders of the Soil Sement test plot during the April 7, 2001 storm monitoring event. However, the product appeared to remain intact during the 2000-2001 storm monitoring season.

As shown on Figure 18, sparse vegetation began to occupy the Soil Sement plot by the February 25-26, 2001 storm event. The vegetation density continued to increase over the remaining 2000- 2001 storm monitoring season.

5.4.1.2 Storm Water Quality Results

As previously stated, storm water samples were collected during only three of the five qualifying storm monitoring events at the 55S site due. Two of the storm monitoring events did not produce sufficient storm water runoff to collect samples for analysis. The storm water quality runoff data for the 55S site are summarized on Table 6. A discussion of the storm water quality runoff results as they relate to the soil and product sample results is presented in Section 6.0.

5.4.2 73S Site

5.4.2.1 Visual Observations

At the 73S site, the control plot (12-204) provided the baseline for comparing the effectiveness of erosion control measures using five erosion control products: Tacking Agent III™ (12-205), Airtrol (12-206), Ultra Tack (12-207), PAM (12-208), and Top Coat (12-209). The following sections summarize the observations made during the course of storm events between February 25 and April 21, 2001 at this site. The occurrence and approximate percentage cover of vegetation growth on the 55S site plots during 2000-2001 study storm season are summarized in Table 5.

<u>Control Plot (12-204)</u>

Figure 19 shows a time-series progression of control plot (12-204) over the 2000-2001storm monitoring season. As previously discussed, the control plot at this location was approximately one-half the size of the other test plots at the 73S site for the February 25-26 and March 6, 2001 storm events. During the intense periods of rainfall, moderate sediment accumulation was observed in the flume and near the intake of the automatic sampler that impeded the accuracy of the level measurements obtained from the bubbler.

Shallow rill formation appeared to develop throughout the plot over the four storm events, with the greatest concentration of rills appearing in the southeastern portion of the test plot during the last event on April 21, 2001.

New vegetation appeared on the control test plot by the April 7, 2001 storm event. The vegetation density continued to increase over the remaining 2000- 2001 storm monitoring season.

<u>Tacking Agent III™ (12-205)</u>

Figure 20 shows a time-series progression of the Tacking Agent III™ test plot. As previously stated, this plot appeared to have the highest runoff volume and sediment load of the six plots at the 73S study site. This may be attributed to: 1) in the first application of Tacking Agent III™, the product was applied only about 2 to 3 hours before rainfall began on February 24, 2001, did not have sufficient time to dry, and appeared to wash off in portions of the plot during the storm event; and 2) some of the product did not adhere to the slope and run off the plot during both applications .

Shallow rill formation was observed in the lower portion of the test plot during the April 7, 2001 storm event. During the April 21, 2001 storm event, shallow rill formation was observed throughout the entire test plot, with the deepest rills observed in the lower portion of the slope.

New vegetation appeared on the Tacking Agent III™ test plot between the March 6 and April 7, 2001 storm events. The vegetation density continued to increase over the remaining 2000-2001 storm monitoring season.

<u>Airtrol (12-206)</u>

Figure 21 shows a time-series progression of the Airtrol test plot. Very little sediment accumulation was observed in the flume and intake of the automatic sampler during the storm events and sediment accumulation did not appear to affect flow measurements obtained from the Airtrol test plot.

Slight rill formation was observed in the central portion of the test plot during the April 7, 2001 storm event. During the April 21, 2001 storm event, shallow rill formation was observed throughout the test plot with the deepest rills observed on the lower, southeastern, and northwestern portions of the slope.

Small patches of vegetation appeared on the Airtrol test plot between the March 6 and April 7, 2001 storm events. The vegetation density continued to increase over the remaining 2000- 2001 storm monitoring season.

<u>Ultra Tack (12-207)</u>

Figure 22 shows a time-series progression of the Ultra Tack test plot. During the February 24-25 and March 6 storm events, very little sediment accumulation was observed in the flume and intake of the automatic sampler. Sediment accumulation during these storm events did not appear to affect flow measurements obtained from the Ultra Tack test plot.

During the April 7 and April 21, 2001 storm events, moderate sediment accumulation was observed in the flume and near the intake of the automated sampler for this test plot. During periods of intense rainfall, the runoff appeared to be turbid and contained a significant amount of sediment. The sediment load impeded the accuracy of flow measurements.

Rill formation was observed in the upper northeastern and central portions of the test plot during the April 7, 2001 storm event. The Ultra Tack product appeared to have been washed off in small areas of the test plot. During the April 21, 2001 storm event, shallow rill formation was observed throughout the test plot with the deepest rills observed on the lower, southeastern, and northwestern portions of the slope.

New vegetation appeared on the Ultra Tack test plot between the March 6 and April 7, 2001 storm monitoring events. The vegetation density continued to increase over the remaining 2000- 2001 storm monitoring season.

PAM (12-208)

Figure 23 shows a time-series progression of the PAM test plot. During the February 24-25 and March 6 storm events, very little sediment accumulation was observed in the flume and intake of the automatic sampler. Sediment accumulation during these storm events did not appear to affect flow measurements obtained from the PAM test plot. During the April 7 and April 21, 2001 storm events, major sediment accumulation was observed in the flume and near the intake of the automated sampler for this test plot. During periods of intense rainfall, the runoff appeared to be turbid and contained a significant amount of sandy sediment. The sediment load impeded the accuracy of flow measurements. Of the six plots at the 73S site, this test plot appeared to have the highest runoff volume and sediment load over the 2000-2001 storm monitoring season.

Rill formation was observed in the lower right-central portion of this slope during the March 6, 2001 monitoring event and deepened and widened with subsequent storm events. Small (1- to 2-inch diameter) animal burrow holes were observed before the April 7, 2001 storm.

New vegetation appeared on the PAM test plot between the March 6 and April 7, 2001 storm events. The vegetation density continued to increase over the remaining 2000- 2001 storm monitoring season.

Top Coat (12-209)

Figure 24 shows a time-series progression of the Top Coat test plot. Very little sediment accumulation was observed in the flume and intake of the automatic sampler during the storm events; however, mulch from the Top Coat application did accumulate in the v-ditch over the 2000-2001 storm monitoring season storm events. The mulch was cleared from the flume to allow more accurate flow measurements. Relative to the other five plots at this site, the Top Coat test plot appeared to have the lowest amount of runoff volume and sediment load over the 2000-2001 storm monitoring season.

Rill formation was not observed on the Top Coat test plot during the course of the four storm monitoring events.

Small patches of vegetation appeared on the Top Coat test plot between the March 6 and April 7, 2001 storm monitoring events. The vegetation density continued to increase over the remaining 2000- 2001 storm monitoring season.

5.4.2.2 Storm Water Quality Results

Storm water samples were collected during four qualifying storm monitoring events at the 55S site. The storm water quality runoff data for the 73S site are summarized on Table 6. A discussion of the storm water quality runoff results as they relate to the soil and product sample results is presented in Section 6.0.

6.0 SUMMARY

The erosion performance and potential export of constituents for each of the tested products are discussed in the following subsections. A discussion of erosion performance is provided in Subsection 6.1. The potential export of constituents is discussed in Subsections 6.2 and 6.3. Product Performance Summaries for each of the tested products are provided in Section 6.4. These summaries include application and performance information. Product information and performance are summarized in Table 7.

6.1 EROSION PERFORMANCE

For the most part, erosion performance of the products was evaluated qualitatively using the results of visually monitoring the plots during and after each storm event. The total suspended solids (TSS) concentrations of the storm water runoff samples were also reviewed to see whether these results could be used to further evaluate erosion performance. Using TSS concentrations to help evaluate erosion performance may be appropriate, provided they correlate with the visual monitoring results. For comparison purposes, four visual monitoring categories (or scores) were selected to represent the erosion control performance observed for each product over each storm event. The scores range from 1 to 4, with a score of 1 assigned to plots with the least evidence of erosion and a score of 4 assigned to plots with the greatest amount of observed erosion. For each storm event, the erosion score of a plot was compared to the concentration of total suspended solids (TSS) in the storm water sample collected from that plot. Plots of erosion score against measurements of TSS are presented on Figures 25 and 26. Inspection of Figures 25 and 26 indicates there is some correlation between the visual monitoring results and TSS. However, there are also some cases where notable erosion was observed and the TSS concentrations were relatively low. Based on these apparent discrepancies, the TSS results were only used as a secondary means of evaluating erosion performance.

To compare the erosion performance of the products with the control plots and with each other, a ranking of “Low”, “Medium”, and “High” was formulated based on the visual monitoring results and to a lesser extent on the results of the TSS analyses. The criteria that define these rankings are provided below.

<u>Erosion Performance - High</u>

- no to very slight sediment load observed in v-ditch and flume during or after storm event;
- no to very minor (i.e., localized and very shallow) rill formation observed on plot after storm event;
- clearing sediment from intake of automatic sampler in v-ditch typically not required during storm; and
- measured TSS in storm water sample typically less than 400 ppm.

<u>Erosion Performance - Medium</u>

- low to moderate sediment load observed in v-ditch and flume during or after storm event;
- minor to moderate rill formation observed on plot after storm event, or further deepening and/or widening of existing rills; and
- occasion to periodic clearing of sediment from intake of automatic sampler in v-ditch typically required during intense portions of the storm event

<u>Erosion Performance - Low</u>

- moderate to high sediment load observed in v-ditch and flume during or after storm event;
- notable rill formation observed on plot after storm event or, further deepening and/or widening of existing rills;

- periodic to nearly constant clearing of sediment from intake of automatic sampler in v-ditch typically required during intense portions of the storm event; and

- measured TSS in storm water sample typically greater than 4,000 ppm

The products are evaluated in Table 7 and in the Product Performance Summaries in Section 6.4 using these defined rankings of erosion. Overall, the seven products on the test plots effectively reduced slope erosion compared to the control plots over the 2000-2001 storm season, or at least initially. Observations of the slopes at the two test sites indicate that the products tested in this study have different life spans. It should be noted that the March 6, 2001 storm event was of low intensity and produced minimal runoff from all plots at both sites. Consequently, there was no to minor erosion observed from the plots and the erosion performance from all plots was ranked as “High” for this storm event.

At the 73S site, PAM, Ultra Tack, and Tacking Agent III™ (without mulch) appear to have limited effective life spans lasting less than one rainy season. These products typically performed well for the first two or so storm events and then their performance declined appreciably thereafter. Conversely, Airtrol and Top Coat appear to have much longer life spans. In general, observations of the plots at the 73S site indicate that Top Coat performed the best for controlling erosion over the entire 2000-2001 storm season.

At the 55S site, EarthGuard™ and Soil Sement performed well as erosion control measures, but may be near the end of their effective life. In general, these two products appeared to perform similarly in controlling erosion. It should be noted that EarthGuard™ and Soil Sement were subjected to one more significant storm event (February 21, 2001) than the 73S site, and caution should be used when comparing performance between sites.

6.2 EXPORT OF CONSTITUENTS

The results of the analytical testing indicate that some constituents were exported from some of the plots. A number of these constituents correlate with the export of total suspended solids. Export of constituents that correlate with the export of total suspended solids is referred to herein as erosion-related export. Export of several other constituents did not appear to be correlated with total suspended solids, but rather appeared specific to individual products or the plots on which the products were applied. This export is referred to herein as possible product-related export. The following subsections discuss the erosion- and product-related exports.

6.2.1 Erosion-Related Export

For the following constituents, the concentrations in runoff correlate with concentrations of total suspended solids:

total aluminum	total chromium	total manganese
total arsenic	total copper	total nickel
total barium	total kjeldahl nitrogen	total vanadium
total cadmium	total lead	total zinc

Figures 27 through 38 demonstrate generally strong correlations between these constituents and total suspended solids. Given the strength of these correlations, it appears that minimizing the formation of total suspended solids, by preventing erosion, will minimize the export of the above constituents.

6.2.2 Possible Product-Related Export

For several constituents, concentrations in runoff were distinctly higher for one or more plots compared to other plots, including the bare plots, and were not correlated with total suspended solids. Identification of distinctly higher concentrations was by inspection; too few data are available to meaningfully apply statistical methods. Such distinctly higher concentrations were classified as possible cases of product-related export. For the following reasons, some uncertainty accompanies these cases. First, identification was by inspection, rather than by use of a statistical method. Second, the one-product-one-plot design confounds the differences between products with differences between the underlying soils in the different plots. An observed difference may be due to the product or it may be due to the underlying soil. Finally, several of the products are applied with mulches. The composition and/or rate of decomposition of the various mulches may account for the differences, rather than the products, which serve only as binders to hold the mulches together.

6.2.2.1 Constituents

Based upon the storm events sampled during this study, higher concentrations that may represent product-related export were observed for the following constituents:

BOD	Nitrate
COD	Dissolved Potassium

DOC	Sulfate
TOC	Total Zinc

In order to assess the significance of the elevated concentrations for the above listed constituents, the detected concentrations are summarized on Table 8 and compared to the analytical results and statistical distribution of runoff samples collected over the 1997 through 1999 wet seasons for the Caltrans statewide characterization project. The results and data comparisons are discussed in the following subsections.

BOD, COD, DOC, and TOC

Distinctly higher concentrations of BOD, COD, DOC, and TOC were measured in runoff from Plot 207, which was treated with UltraTack and mulch (Figures 39 through 41). The COD, DOC, and TOC measurements for Plot 12-207 appear to represent the same material exported from the plot. The concentrations measured for DOC and TOC are virtually identical for each storm. The corresponding concentrations of COD appear to track those of DOC and TOC. The concentrations of all three also rise with each succeeding storm. BOD for Plot 12-207 is exhibits behavior opposite to the other three. It is highest for the first storm and is relatively low for succeeding storms.

As shown on Table 4, of all the product samples included in this study and submitted for chemical analysis, Ultra Tack had the second highest detected concentrations of COD, DOC, and TOC (2920 milligrams per liter (mg/l), 1190 mg/l, and 1200 mg/l, respectively) and the fourth highest BOD concentration (594 mg/l).

As shown in Table 8, the detected COD concentrations fall between the approximate 50th and 90th percentile of the statewide characterization results. There are no statewide characterization results for DOC. The TOC concentrations for the first three storms fall between the 75th and 95th percentile of the statewide results and the concentration from the fourth storm is significantly above the 95th percentile of the statewide results. The BOD concentration from the first storm is significantly higher that the 95th percentile of the statewide results. The results from subsequent storms are no higher than the 50th percentile of the statewide characterization results.

Nitrate

Distinctly higher concentrations of nitrate were detected in runoff samples from certain storms for Plots 12-203 and 12-207, which were treated with Soil Sement and UltraTack/mulch, respectively (Figure 42). High nitrate concentrations were detected in samples collected from

Plot 12-203 in the first storm and from Plot 12-207 for its third storm. Nitrate was not detected in either the Soil Sement or Ultra Tack product samples submitted for analysis (Table 4).

The elevated results for both Soil Sement and Ultra Tack/mulch fall near the 90th percentile of the statewide characterization results (Table 8).

Dissolved Potassium

A distinctly higher concentration of dissolved potassium was measured in runoff during the first storm for Plot 12-203, which was treated with Soil Sement (Figure 43). In the second storm, the potassium concentration was slightly, but not distinctly higher than for Plots 12-201 and 12-202. Chemical analysis of Soil Sement (Table 4) indicates that the product contains potassium at a concentration of 1400 micrograms per liter (μg/l).

There are no statewide characterization results for dissolved potassium.

Sulfate

Distinctly higher concentrations of sulfate were measured in runoff during the first storm on each of Plots 12-203 and 12-206, which were treated with Soil Sement and Airtrol, respectively (Figure 44). During the third storm for the 73 site, sulfate concentrations were higher for all of the plots, including Plot 12-206, than in the first storm, suggesting that relatively high sulfate concentrations were present in the rain falling on the site. During the second storm for the 73S site, Plot 12-208, which was treated with PAM, appeared to have a higher sulfate concentration; however, for that storm the concentrations of all the plots, except Plot 12-206, were higher than the first storm, though not as high as the third storm.

Sulfate was detected at a concentration of approximately 60 milligrams per kilogram (mg/kg) in the Soil Sement product sample submitted for analysis (Table 4). Sulfate analysis on the Airtrol product sample was not performed, however, the primary constituents in Airtrol include Plaster of Paris (which cures to gypsum), and gelatin (hydrolyzed keratin). Gypsum is calcium sulfate dihydrate and is modestly soluble in water. The appearance of sulfate in the runoff from Plot 206 during the first storm could be due to dissolution of the gypsum.

The elevated sulfate concentrations detected in sampled collected from the first storm for the Soil Sement and Airtrol plots are significantly higher than the 95th percentile of the statewide characterization results for sulfate (Table 8).

Total Zinc
Although total zinc concentrations were correlated with total suspended solids, the total zinc concentration in runoff during the first storm for Plot 12-209, which was treated with Top Coat, was distinctly higher than the correlation would predict (Figures 45 and 38, respectively). Chemical analysis of Top Coat (Table 4) indicates that the product contains zinc at a concentration of 480 micrograms per liter (μg/l).

The detected zinc concentration from the first storm for the Top Coat plot falls between the 75th and 90th percentile of the statewide characterization results (Table 8).

6.3 PRODUCT PERFORMANCE SUMMARIES

This section provides a separate summary of each product tested during the 2000/2001 storm season. The summaries provide an overview of the product and highlight the findings of study that are specific to the product.

PRODUCT PERFORMANCE SUMMARY

EARTHGUARD™

Caltrans Temporary/Permanent
Soil Stabilization Study

District 12 - 55S Orange County Study Site

The following is a summary of the performance of EarthGuard™ as an erosion control product and resultant effect, if any, of this product on storm water quality. It includes the intended use and erosion control application; the recommended method for application including rate and drying time; and the general integrity and endurance of EarthGuard™ as an erosion control product. The findings of the field and laboratory evaluation of this product are also summarized.

EarthGuard™ was applied to a field test plot located at the District 12, 55S Orange County Study Site located at the intersection of the 55S and 73 freeways. The test plot was a 0.2 acre, 2:1 (H: V) sloped highway embankment approximately 20 to 30 feet high. The slope was constructed of compacted fill consisting of sandy clay.

PRODUCT DESCRIPTION

Product name: EarthGuard™
Chemical Makeup: 30 percent anionic polyacrylamid/ammonium acrylate in water-in-oil emulsion
Physical Properties: Grayish-white, viscous emulsion; faint ammonia odor; pH 6 to 8 (upon dilution in water)

RECOMMENDED PRODUCT USE

EarthGuard™ has a high molecular weight and specific charge density, which enhances soil particle aggregation. The product can be applied for temporary erosion control lasting up to one season. The actual length of the product effectiveness is dependent upon a number of factors including climate, slope inclination, and soil/geologic conditions.

According to the manufacturer, EarthGuard™ is effective for erosion control, slope stabilization, dust abatement, storm water run-off and silt control, and water quality control. EarthGuard™ was used in this study to evaluate its effects on erosion control and affects on storm water quality. The product is not intended for vehicular traffic; however, it can be effective for dust suppression along roadways.

Recommended Application Method, Rate, and Drying Time

EarthGuard™ is typically applied as a spray to the soil surface. For erosion and sedimentation control, the material should be mixed with a mulch and a minimum of 3,000 gallons of water per acre. The actual amount of product used in the mixture is dependent upon the inclination of the slope to be treated. The product can be applied in any weather; however, field conditions that result in runoff of product during application should be avoided.

Findings

The performance of the test plot treated with EarthGuard™ was monitored during a portion of the 2000/2001 wet season. Representative samples of storm water runoff were collected and analyzed from three storm events producing runoff from the test plot and the results were compared to results from an untreated control plot consisting of bare soil. In addition, visual monitoring of erosion control performance was conducted during and after five storm events. The following provides a summary of the findings related to erosion control performance and potential water quality impacts from EarthGuard™.

- The three storms monitored during this study had total rainfall amounts of 1.35, 1.81, and 0.31 inches with corresponding average intensities of 0.131, 0.04, and 0.068 inches per hour.

- Erosion performance for EarthGuard™ was good. Using the erosion control performance ranking criteria, the qualitative evaluation of erosion control performance from the EarthGuard™ test plot was "High" for the five storms monitored. The total suspended solids concentration of runoff samples collected from the EarthGuard™plot were approximately one-one hundredth the concentration for the adjacent untreated control slope.

- No product related export was noted in runoff samples collected from the EarthGuard™ test plot; however, foaming was noted in the runoff during the first storm event.

- The life span of EarthGuard™ product appears to be more than the five storm events monitored in this study.

PROJECT PERFORMANCE SUMMARY

SOIL SEMENT™

Caltrans Temporary/Permanent
Soil Stabilization Study
2000/2001 Season

District 12 - 55S Orange County Study Site

The following is a summary of the performance of Soil Sement™ as an erosion control product and resultant effect, if any, of this product on storm water quality. It includes the intended use and erosion control application; the recommended method for application including rate and drying time; and the general integrity and endurance of Soil Sement™ as an erosion control product. The findings of the field and laboratory evaluation of this product are also summarized.

Soil Sement™ was applied to a field test plot located at the District 12, 55S Orange County Study Site located at the intersection of the 55S and 73 freeways. The test plot was a 0.1 acre, 2:1 (H: V) sloped highway embankment approximately 20 to 30 feet high. The slope was constructed of compacted fill consisting of clayey sand.

PRODUCT DESCRIPTION

Product name – Soil Sement™
Chemical Makeup – Aqueous acrylic vinyl acetate polymer emulsion
Physical Properties – Milky white liquid; characteristic acrylic odor; pH 4.0 to 9.5

RECOMMENDED PRODUCT USE

Soil Sement™ is used primarily for soil stabilization and as a dust control agent. The product was used for soil stabilization and erosion control as part of this study. This product is not generally used to support vehicular traffic.

RECOMMENDED APPLICATION METHOD, RATE, AND DRYING TIME

Soil Sement™ is designed to be applied as a spray using a standard water truck or used as a tackifer during hydroseeding. The amount of Soil Sement™ applied to a site is dependent upon soil texture and slope. At the study site Soil Sement™ was applied by the manufacturer at a rate of 670 gallons per acre or about 1 gallon per 65 square feet. Soil Sement™ is most effective if applied on either dry or slightly moist soil. Excessive moisture will dilute the application rate. Drying time is dependent upon weather conditions including temperature, humidity and wind. Typical drying times may be 8 hours for an overcast day and 2 hours on a sunny day.

FINDINGS

The performance of the test plot treated with Soil Sement™ was monitored during a portion of the 2000/2001 wet season. Representative samples of storm water runoff were collected and analyzed from two storm events producing sufficient runoff from the test plot and the results were compared to results from an untreated control plot consisting of bare soil. In addition, visual monitoring of erosion control performance was conducted during and after five storm events. Three of the five storm events produced sufficient runoff to observe erosion conditions. The following provides a summary of the findings related to erosion control performance and potential water quality impacts from Soil Sement™.

- The two storms analytically monitored during this study had total rainfall amounts of 1.32 and 1.78 inches with corresponding average intensities of 0.13 and 0.04 inches per hour.

- Erosion performance for Soil Sement™was good. Using the erosion control performance ranking criteria, the qualitative evaluation of erosion control performance from the Soil Sement™ test plot was "High" for the five storms monitored. The total suspended solids concentration of runoff samples collected from the Soil Sement™ plot were approximately one-one hundredth the concentration for the adjacent untreated control slope.

- Distinctly higher concentrations of sulfate were measured in runoff during the first storm from the plot treated with Soil Sement™. Sulfate was detected at a concentration of approximately 60 milligrams per kilogram (mg/kg) in the Soil Sement™ product sample submitted for analysis.

- The life span of Soil Sement™appears to be more than the five storms monitored in this study.

PRODUCT PERFORMANCE SUMMARY

TACKING AGENT III™

Caltrans Temporary/Permanent
Soil Stabilization Study
2000/2001 Season

District 12 - 73S Orange County Study Site

The following is a summary of the performance of Tacking Agent III™ as an erosion control product and resultant effect, if any, of this product on storm water quality. It includes the intended use and erosion control application; the recommended method for application including rate and drying time; and the general integrity and endurance of Tacking Agent III™ as an erosion control product. The findings of the field and laboratory evaluation of this product are also summarized.

Tacking Agent III™ was applied to a field test plot a the Caltran District 12, 73S Orange County Study Site located approximately one mile south of Newport Coast Drive on the southbound Highway 73. The product was applied to the slope on two separate occasions. In both applications, Tacking Agent III™ was applied without mulch, which according to the manufacturer, is an acceptable method. Precipitation within about two hours after the first application did not allow ample drying time, and prevented the product from completely drying and adhering to the slope. Consequently, Tacking Agent III™ was reapplied under dry climatic conditions, allowing the product to thoroughly dry. However, during both applications, it was observed that a portion of the product did not adhere to the slope and ran off the plot.
The test plot was a 0.2 acre, 2:1 (H:V) sloped highway embankment approximately 55 feet high. The slope was constructed of a compacted fill consisting of silty sand.

PRODUCT DESCRIPTION

Product name: Tacking Agent III™
Chemical Makeup: Polyacrylamide and copolymer of acrylamide
Physical Properties: Light Green; no odor; pH 7.0

RECOMMENDED PRODUCT USE

Tacking Agent III™ is used as tackifier for binding mulch and seed in during hydroseeding operations. The product is often used to aid in establishment of vegetation; however, it can be used without mulch as a temporary soil erosion control measure.

RECOMMENDED APPLICATION METHOD, RATE, AND DRYING TIME

Tacking Agent III™ is sprayed on using a hydroseeding machine. Application rates when using mulch or when applying the product alone are dependent upon the inclination of the slope. Tacking Agent III™ was applied on the demonstration plot for this study at a mix ration of 16 pounds of product and 500 gallons of water. This ratio equates to about 80 pounds per acre and about 2,500 gallons. Drying time for Tacking Agent III™ is about 2 to 4 hours and is dependent on existing climatic conditions. The product should be applied on dry to moist surface conditions and should not be applied in the rain.

FINDINGS

The performance of the test plot treated with Tacking Agent III was monitored during a portion of the 2000/2001 wet season. Representative samples of storm water runoff were collected and analyzed from three storm events producing runoff from the test plot and the results were compared to results from an untreated control plot consisting of bare soil. In addition, visual monitoring of erosion control performance was conducted during and after four storm events. The following provides a summary of the findings related to erosion control performance and potential water quality impacts for Tacking Agent III.

- The three storms monitored during this study had total rainfall amounts of 2.18, 0.63, 0.31 inches with corresponding average intensities of 0.064, 0.058, and 0.121 inches per hour.

- Tacking Agent III ™ was applied on the test plot twice during this study. In both cases, the product was applied without mulch, which according to the manufacturer is an acceptable method for application. However, the amount of product remaining on the slope after application appeared very limited. In the case of the first application, the product may have not fully cured and may have washed from the slope during the first storm event. In the second case, it appeared that some of the product did not adhere to the slope surface and ran off during application. Based on these observations, it appears that this product should not be used on a slope surface without mulch.

- Using the erosion control performance ranking criteria, the qualitative evaluation of erosion for the Tacking Agent III™ test plot was "Low" for the four storm events monitored. The total suspended solids concentrations in runoff water collected from the test plot generally were comparable to the adjacent untreated control plot. However, the amount of product remaining on the slope after both applications appeared limited and its poor erosion performance during this study may be the result of not including a mulch with application.

- No indication of product related export was observed for Tacking Agent III™ .

PRODUCT PERFORMANCE SUMMARY
ULTRA TACK™
Caltrans Temporary/Permanent
Soil Stabilization Study
2000/2001 Season
District 12 - 73S Orange County Study Site

The following summarizes the performance of Ultra Tack™ as an erosion control product and resultant effect, if any, of this product on storm water quality. It includes the intended use and erosion control application; the recommended method of application including rate and drying time; and the general integrity and endurance of Ultra Tack™ as an erosion control product. The findings of the field and laboratory evaluation of this product are also summarized.

Ultra Tack™ was applied to a field test plot located at the District 12, 73S Orange County Study Site located approximately one mile south of Newport Coast Drive on the southbound 73 Freeway. The test plot was a 0.2 acre, 2:1 (H:V) sloped highway embankment approximately 55 feet high. The slope was constructed of fill consisting of silty sand.

Product Description

Product Name: Ultra Tack™; Anionic Polyacrylamide
Chemical Makeup: 18 mole percent anionic polyacrylamide powder, sodium salt
Physical Properties: Off-white granular solid

Recommended Product Use
Ultra Tack™ is an anionic polyacrylamide that is typically used as a tackifier and binding agent that can last as long as six months. The product is typically mixed with mulch and a hydroseed mixture and sprayed on the ground surface to improve seed germination and quicker plant establishment.

Recommended Application Method, Rate, and Drying Time
Ultra Tack™ is applied as a liquid spray with a hydroseeding machine. The mixing ratio is about 3 to 5 pounds per acre mixed with about 1,600 pounds of mulch and about 3,000 gallons of water. For this demonstration study, Ultra Tack™ was applied to a 0.2-acre test plot at a mix ratio of 5 pounds of product, 325 pounds of mulch and 600 gallons of water. The product

application rate used in this study was approximately 25 pounds per acre, which was slightly higher than the rate recommended by the manufacturer because the product was being evaluated as an erosion control product rather than a tackifier or bonding agent. Ultra Tack^{TM} requires about 2 to 4 hours to dry; however, this time is dependent upon temperature, humidity and wind.

Findings

The performance of the test plot treated with Ultra Tack^{TM} was monitored during a portion of the 2000/2001 wet season. Representative samples of storm water runoff were collected and analyzed from four storm events producing runoff from the test plot and the results were compared to results from an untreated control plot consisting of bare soil. In addition, visual monitoring of erosion control performance was conducted during and after each of the four storm events. The following provides a summary of the findings related to erosion control performance and potential water quality impacts for Ultra Tack^{TM}.

- The four storms monitored during the study had total rainfall amounts of 2.34, 0.43, 0.71, and 0.32 inches with corresponding average intensities of 0.068, 0.097, 0.061 and 0.128 inches per hour.

- Erosion control performance for Ultra Tack^{TM} was good for the first and second storms, but fair to poor for the third and fourth. Using the erosion control performance ranking criteria, the qualitative evaluation of erosion control for the Ultra Tack^{TM} test plot was "High" for the first and second storms, "medium" for the third and fourth storm events. The total suspended solids concentrations in runoff water collected from the test plot were approximately one-one hundredth the concentration of the adjacent untreated control plot.

- Possible product-related export of BOD, COD, DOC and nitrate were noted in storm water runoff samples collected from the Ultra Tack^{TM} test plot. Analysis of Ultra Tack^{TM} for BOD, COD, DOC, and TOC indicate that these constituents are present in Ultra Tack^{TM} at concentrations that are somewhat higher than or comparable to the other products tested. The source of these constituents may be the product, but also could be the particular mulch used or the underlying soil in the Ultra Tack^{TM} plot. No nitrate was detected in Ultra Tack^{TM}; however, nitrate appeared in later storms suggesting that it was generated by decomposition and oxidation of ammonia or organic nitrogen.

- The COD concentrations from the Ultra Tack^{TM} test plot fall between the approximate 50th and 90th percentile of the Caltrans statewide characterization results. There are no statewide characterization results for DOC. The TOC concentrations for the first three storms fall between the 75th and 95th percentile of the statewide results and the concentration from the fourth storm is significantly above the 95th percentile of the statewide results. The BOD concentration from the first storm is significantly higher that the 95th percentile of the statewide results. The results from subsequent storms are no higher than the 50^{th} percentile of the statewide characterization results.

- Based on the observed erosion control effectiveness the life span of the Ultra Tack™ product appeared to be approximately 2 storms.

PRODUCT PERFORMANCE SUMMARY
AIRTROL™
Caltrans Temporary/Permanent
Soil Stabilization Study
2000/2001 Season
District 12 - 73S Orange County Study Site

The following is a summary of the performance of AIRTROL™ as an erosion control product and resultant effect, if any, of this product on storm water quality. It includes the intended use and erosion control application; the recommended method for application including rate and drying time; and the general integrity and endurance of AIRTROL™ as an erosion control product. The findings of the field and laboratory evaluation of this product are also summarized.

AIRTROL™ was applied to a field test plot at the Caltrans District 12, 73S Orange County Study Site located approximately one mile south of Newport Coast Drive on the southbound Highway 73. The test plot was a 0.2 acre, 2:1 (H: V) sloped highway embankment approximately 55 feet high. The slope was constructed of compacted fill consisting of silty sand.

Product Description
Product Name: AIRTROL™
Chemical Makeup: Mixture of plaster of paris and hydrolyzed keratin (calcium sulfate hemihydrate).
Physical Properties: Off-white to gray powder; low odor; pH 7.5 to 8.5.

Recommended Product Use
AIRTROL™ is cementious plaster binder produced from high-purity gypsum and applied in conjunction with a cellulose or wood fiber mulch through a hydraulic process. The product forms a uniform protective crust-like barrier that reduces water and wind induced erosion. AIRTROL™ is typically used for erosion control and as a cover for establishing vegetation on disturbed slope areas.

Recommended Application Method, Rate, and Drying Time

AIRTROL™ is typically applied as a part of a bonded fiber matrix consisting of water, and cellulose or wood fiber. The manufacturer recommends a mix ratio of 6,000 pounds of AIRTROL™, 1,600 pounds of mulch fiber and 4,000 gallons of water per acre. The product is typically applied to slopes of 4:1 or greater and is sprayed uniformly over the area to be treated using a hydroseeder/hydromulcher. For this study, the product was applied on an approximately 0.2 acre test plot using a hydroseeding machine at a mix ratio recommended by the manufacturer of 1,000 pounds of AIRTROL™, 300 pounds of fiber mulch, and 600 gallons of water. The product should be not be applied during rain events, to excessively moist soil, or when wind gusts exceed 25 miles per hour. Product drying time is between 4 and 8 hours, but is dependent upon temperature, humidity, and wind.

Findings

The performance of the test plot treated with AIRTROL™ was monitored during a portion of the 2000/2001 wet season. Representative samples of storm water runoff were collected and analyzed from two storm events producing runoff from the test plot and the results were compared to results from an untreated control plot consisting of bare soil. In addition, visual monitoring of erosion control performance was conducted during and after four storm events. The following provides a summary of the findings related to erosion control performance and potential water quality impacts for AIRTROL™.

- The two storms with sufficient rainfall for monitoring during this study had total rainfall amounts of 2.17 and 0.30 inches with corresponding peak average intensities of 0.065 and 1.12 inches per hour.

- Erosion control performance for AIRTROL™ was good. Using the erosion control performance ranking criteria, the qualitative evaluation of erosion control for the AIRTROL™ test plot was "High" for the four storm events for which the plot was visually monitored. The total suspended solids concentrations in runoff water collected from the test plot were approximately one-one hundredth the concentration of the adjacent untreated control plot.

- Possible product-related export of sulfate from the AIRTROL™ test plot was noted during the first storm event. The appearance of sulfate in the runoff from the AIRTROL™ plot could be due to the dissolution of gypsum (Plaster of Paris), which is the primary constituent in AIRTROL™.

- The elevated sulfate concentrations detected in sampled collected during the first storm from AIRTROL™ plot is significantly higher than the 95th percentile of the statewide characterization results for sulfate

- The life span of the AIRTROL™ product appears to be more than the four storm events monitored during this study.

PRODUCT PERFORMANCE SUMMARY
POLYACRYLAMIDE (Chemco 9107GD)
Caltrans Temporary/Permanent
Soil Stabilization Study
2000/2001 Season

District 12 - 73S Orange County Study Site

The following is a summary of the performance of Polyacrylamide (PAM) as an erosion control product and resultant effect, if any, of this product on storm water quality. It includes the intended use and erosion control application; the recommended method for application including rate and drying time; and the general integrity and endurance of PAM as an erosion control product. The findings of the field and laboratory evaluation of this product are also summarized.

PAM product was applied to a field test plot at the District 12, 73S Orange County Study Site located approximately one mile south of Newport Coast Drive on the southbound 73. The test plot was a 0.2 acre, 2:1 (H:V) sloped highway embankment approximately 55 feet high. The slope was constructed of compacted fill consisting of silty sand.

PRODUCT DESCRIPTION

Product name: Polyacrylamide- PAM- (Chemco 9107GD)
Chemical Makeup: Anionic polyacrylamide – high molecular weight (15mg/mole) and highly anionic charge density.
Physical Properties: Off-white granular powder; no discernible odor.

RECOMMENDED PRODUCT USE

PAM is a long-chain organic polymer developed to clarify drinking water. PAM has also been used for erosion control, enhanced infiltration and nutrient removal. The product has become a BMP for erosion control because of it ability to conveniently and inexpensively stabilize soils and remove fine suspended sediments from storm water.
If the treated area is disturbed by foot and/or vehicle traffic the product will not be effective and will need to be reapplied.

Recommended Application Method, Rate, and Drying Time

PAM can be applied as a dry form or as a liquid. In a dry form PAM can be applied using a seeder or fertilizer spreader. In a liquid form PAM is applied using a water truck or sealed hydro spray rig. According to recommendations from Washington Department of Transportation, PAM should be applied at a rate not to exceed 0.5 pounds per acre mixed in 1,000 gallons of water. The recommended dry product application rate is about five to ten pounds per acre; however, this method of applying the product is less desirable and considerably less effective than spraying. PAM may need to be reapplied to a site several times throughout the rainy season. According to recommendations by the Washington Department of Transportation, PAM should not be applied more than once in a 48-hour period and the maximum number of applications of PAM shall not exceed 7 in any 30-day period.

Findings

The performance of the test plot treated with PAM was monitored during a portion of the 2000/2001 wet season. Representative samples of storm water runoff were collected and analyzed from three storm events producing runoff from the test plot and the results were compared to results from an untreated control plot consisting of bare soil. In addition, visual monitoring of erosion control performance was conducted during and after four storm events. The following provides a summary of the findings related to erosion control performance and potential water quality impacts from PAM.

- The three storms with sufficient runoff for monitoring during this study had total rainfall amounts of 2.26, 0.62, and 0.28 inches with corresponding average intensities of 0.066, 0.057, and 0.131 inches per hour.

- Erosion performance for PAM was good for the first two storms, but poor for the remaining storms. Using the erosion control performance ranking criteria, the qualitative evaluation of erosion control for the PAM test plot was “High” for the first two storms and “Low” for the remaining two storms. After the first storm event, the total suspended solids concentration of runoff samples collected from the PAM plot were comparable to the concentrations from the untreated control plot.

- Possible product-related export of sulfate from the PAM test plot was noted in runoff samples collected during the second storm event.

- The life span of PAM product appeared to be limited to one to two storm events.

EROSION CONTROL PERFORMANCE EVALUATION

TOPCOAT™

Caltrans Temporary/Permanent
Soil Stabilization Study
District 12 - 73S Orange County Study Site

The following is a summary of the performance of TOPCOAT™ as an erosion control product and resultant effect, if any, of this product on storm water quality. It includes the intended use and erosion control application; the recommended method for application including rate and drying time; and the general integrity and endurance of TOPCOAT™ as an erosion control product. The findings of the field and laboratory evaluation of this product are also summarized.

TOPCOAT™was applied to a field test plot at the Caltrans District 12, 73S Orange County Study Site located approximately one mile south of Newport Coast Drive on the southbound Highway 73. The test plot was a 0.2 acre, 2:1 (H: V) sloped highway embankment approximately 55 feet high. The slope was constructed of compacted fill consisting of silty sand.

PRODUCT DESCRIPTION

Product name: TOPCOAT™
Chemical makeup: Cellulose Based Fibers with proprietary filler
Physical properties: Finely divided material; tan in color; no discernible odor; pH 8.6.

RECOMMENDED PRODUCT USE

TOPCOAT™ is designed to be used as a daily cover material for landfills. However, representatives of the manufacturer reported that the product has also been used as an effective erosion control measure and suggested that it be included in this study. The manufacture reports that a single application of TOPCOAT™ near Phoenix, Arizona has been effectively controlling erosion for two seasons. Because it is a paper product, the durability of the product is limited and vehicular traffic should be avoided.

RECOMMENDED APPLICATION METHOD, RATE, AND DRYING TIME

TOPCOAT™ is applied using a hydrospray machine. The recommended product application rate is 3,500 pounds of material with 5,000 gallons of water per acre. A single bale of

TOPCOAT™ weighs about 50 pounds. TOPCOAT™ was applied in this study over an area of about 0.2 acres at a rate of about 700 pounds of product and 1000 gallons of water.

FINDINGS

The performance of the test plot treated with TOPCOAT™ was monitored during a portion of the 2000/2001 wet season. Representative samples of storm water runoff were collected and analyzed from two storm events producing runoff from the test plot and the results were compared to results from an untreated control plot consisting of bare soil. In addition, visual monitoring of erosion control performance was conducted during and after four storm events. The following provides a summary of the findings related to erosion control performance and potential water quality impacts from TOPCOAT™.

- The two storms monitored during this study had total rainfall amounts of 2.45 and 0.64 inches with corresponding average intensities of 0.07 and 0.06 inches per hour.

- Erosion control performance for TOPCOAT™ was good. Using the erosion control performance ranking criteria, the qualitative evaluation of erosion control for the TOPCOAT™ test plot was "High" for the four storms monitored. The total suspended solids concentration of runoff samples collected from the TOPCOAT™ plot were between one-tenth and one-one hundredth the concentration for the adjacent untreated control slope.

- Possible product-related export of total zinc from the TOPCOAT™ test plot was noted in runoff samples collected during the first storm event. Chemical analysis of the product indicates that TOPCOAT™ contains zinc at a concentration of 480 micrograms per liter.

- The detected zinc concentration from the first storm for the TOPCOAT™ plot falls between the 75th and 90th percentile of the Caltrans statewide characterization results.

- The life span of TOPCOAT™ product appears to be more than the four storm events monitored for this study.

7.0 RECOMMENDATIONS

Based upon the findings of this study, the study team recommends the following:

1. The visual and analytical findings from this study should be compared to the findings of San Diego State's on-going simulated runoff study.

2. Caltrans should consider performing additional field testing using the plots installed for this study based upon the following.

   - Additional field data may be useful to substantiate the findings from this study in the event that significant differences between the San Diego State and this study are identified.

   - There are many temporary non-vegetative products used by Caltrans for which water quality and independent erosion performance information is not available. The existing test sites can be used to evaluate these untested products.

   - For existing products more commonly used by Caltrans or new products that may beneficial to Caltrans, the plots can be used to study and optimize product application rates, mixtures, and techniques. For example, the 2000/2001 study indicated that Tacking Agent III without mulch was not effective in controlling erosion. Additional testing of this product with mulch could be performed for comparison. Based upon the finding from such a study, a guidance document and/or standardized operating procedures could be prepared and distributed within Caltrans and to Caltrans' contractors.

8.0 REFERENCES

Brown and Caldwell, 1998, Statewide Roadside Erosion Review, prepared for California Department of Transportation, Sacramento, California, July

California Department of Transportation, 2000, Guidance Manual: Stormwater Monitoring Protocol, Second edition, July.

California Department of Transportation, 2001, Sampling and Analysis Plan, Caltrans Temporary/Permanent Soil Stabilization Evaluation Study (CTSW – RT-01-001), prepared for California Department of Transportation, Sacramento, California, March.

California Department of Transportation, 2001, Detailed Study Plan and Experimental Design, Caltrans Temporary/Permanent Soil Stabilization Evaluation Study, (CTSW-RT-01-014), prepared for California Department of Transportation, Sacramento, California, March.

California Department of Transportation, 2000, Caltrans District 7 Erosion Control Pilot Study, prepared for California Department of Transportation, Sacramento, California, June.

California Department of Transportation, 2000, Soil Stabilization for Temporary Slopes, prepared for California Department of Transportation, Sacramento, California, June.

Woodward Clyde, 1998, District 7 Erosion Control Pilot Study: Detailed Study Plan and Experimental Design, prepared for California Department of Transportation, Sacramento, California.